

LOW TEMPERATURE
DISTILLATION OF WYOMING COAL

BY

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ARMOUR INSTITUTE OF TECHNOLOGY

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The low temperature

distillation of a Wyoming

THE LOW TEMPERATURE DISTILLATION OF A WYOMING COAL

A THESIS

PRESENTED BY

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PRESIDENT AND FACULTY

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THE LOW TEMPERATURE DISTILLATION OF A
WYOMING COAL

by

C. L. Bolte and F. F. Durent.

The material presented in the following report covers the experimental work performed during the months of March, April, and May, 1916, in the Industrial Chemistry Laboratory of the Armour Institute of Technology.

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Introductory.

There has been a comparatively small amount of research done in investigating the distillation of coal at low temperatures. According to Wagner¹ "low temperature carbonization has received but little attention in the United States, but quite some successful work has been done in this direction in Europe". The work in Europe has had as its principal object the production of a smokeless fuel from bituminous coals. Parr² says of "coalite", a fuel of this sort produced in England since 1907, under a British patent, "the method consists in subjecting any bituminous coal to a temperature approaching 800° F (426° C) in a closed rectangular retort, placed vertically in a gas fired furnace for about eight hours. According to the claims made for coalite, the yield and by-products will compare favorably with those obtained in the manufacture of illuminating gas."

Parr and Olin have given considerable attention

1. Wagner: Coal and Coke, Chapter XIII.
2. Parr: Modification of Illinois Coal by Low Temperature Distillation. U. of Ill. Bul. 24.
3. Parr and Olin: Univ. of Ill. Eng. Expt. Sta. Bulletins 60 and 71.

to the low temperature distillation of coal since 1907, and according to Wagner have developed the following three lines of industrial interest.

1. Their attention has been drawn to the possibility of developing a fuel of good texture which will be suitable for general industrial use, and they assert that the by-products obtained while making such a fuel promise to be of especial value. These products consist of a gas of high illuminating and calorific power; of ammonia, the quantity of which will of course be less than that obtained at high temperatures; and tar, the latter being composed almost entirely of oils, containing a minimum quantity of pitch and free carbon.

2. A possible method is suggested for the production of a producer gas which would be free from present difficulties attending the use of bituminous coal, and which would convert a much larger percentage of the fuel into gaseous form.

3. Quite interesting possibilities in the production of coke are opened up by the application of this process; this also holds good for the production of

briquettes or other forms of manufactured fuel into a dense and stable form of such consistency as will meet the requirements of shipping, storage, foundry, or other industrial uses.

These experiments have developed the following fundamental facts:

1. The formation of coke depends upon the presence of certain constituents having a melting point which is lower than the temperature at which decomposition or carbonisation takes place.

2. Oxidation of these compounds may easily take place and the greatest coking effect is obtained where the opportunity for the minimum amount of oxidation has occurred. The condition prescribed, therefore, is that there shall be the least possible exposure to oxidation either before or during the process of carbonisation.

3. Coals containing an excessive quantity of the coking substance produce a light porous coke. The texture of the product may be modified by the use of pressure, and by close packing of the charge, and especially by mixing with material which has already passed through the coking process.

Such a mixture provides the physical condition whereby the gases formed may readily pass out of the mass without carrying along the cementing substances.

4. By the use of temperatures between 400°C and 500°C all of the resulting products are of a type distinctly different from those obtained by the usual high temperature procedure.

The coke resulting from the low temperature process has from 18% to 20% volatile matter remaining, but since it has been heated above 400°C there should be none of the tar constituents remaining. The most convincing test on this point, as also the best method for arriving at a conclusion as to its adaptability for such work, was to try out the material in a suction gas producer.* The results indicated that no clogging effect whatever results, thus showing the absence of tar bodies. The physical operation of the producer as well as the grade of gas produced was fully equal, if not superior to the output when anthracite was used.

* This work was carried on by Prof. Larr, and not in connection with the present investigation.

The semi-coke has such an amount of volatile matter remaining, together with the right degree of coherence as to make it especially adaptable for household use. It is clean to handle, free from dust, and burns without the formation of smoke or soot. Especially to be noted in this connection is its ability to retain a fire without undue attention to drafts, etc.,

The average specific gravity of the tar is 1.069. It is rich in low boiling distillate passing over at 210°C . This product averages about 18% of the total. The pitch residue amounts to approximately 30%, and is remarkably free from precipitated carbon.

The adaptability of the tar for wool preservation processes seems to be indicated by the high percentage of tar acids. These constituents make up from 28% to 30% of the crude material. The larger part, about 22% is found in the second distillate, or heavy oil, from 210°C to 325°C , only about 7% coming over below 210°C .

Approximately 10% of the tar is found to be low boiling distillate free from tar acid, and suitable for use in internal combustion engines.

Harr stated that naphthalene is present, but it was quite evidently present, and in some tar in considerable quantities, as was also anthracene. It was not possible in the present investigation to determine quantitatively as many things as was desired, and among those were naphthalene and anthracene, whose presence was only indicated.

The free carbon in the crude tar was low, and the residual product after the light distillate and heavy oils are removed would be classed as hard pitch.

A principal feature results from this study of these various substances, namely that all three of the general divisions of coke, gas, tar, have specific properties of an especially valuable sort, which would indicate that the process of coking at low temperatures could be established successfully on a commercial basis."

General:

The distillation of coal is carried on by heating the coal in a closed retort, with one exit through which the products of the distillation pass into the receivers. The exclusion of air thus prevents more than an inappreciable oxidation of the products, keeping the undesirable carbon dioxide gas to a minimum. Commercially the operation is carried on under normal pressures, there being just enough pressure to insure flow through the line, to overcome the opposition of the various elements in the line.

Three different samples of coal were used in the present investigation, and each was distilled under three different conditions: 1. normal pressure; 2. partial vacuum; 3. atmosphere of steam; the object being to discover any appreciable difference in the amount, character, and composition of the products from the same sample under different conditions.

By-product coking is usually done at temperatures of about 1100°C . In the present investigation the maximum temperature was 550°C . This was reached gradually at the end of three hours heating, and the temperature was maintained for three hours, or until the distillate

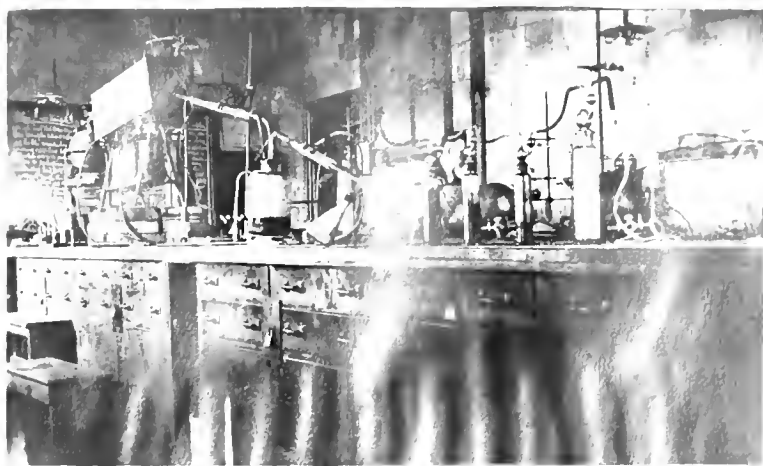
ceeded to come over. The object in using low temperature was to discover, by comparison with results from previous investigations carried on at higher temperatures, whether the low temperatures might not just as well be used with practically the same output of more desirable products, and with a like saving in heat expenditure.

Apparatus:

The still or reactor used was a horizontal cylindrical one, made from a length of wrought iron pipe five inches in diameter and thirty inches long. This was securely capped at each end. The still was held in a strap-iron stand at a height of about three feet from the table. The stand likewise supported a burner made from a length of one inch pipe, and slotted transversely at every four inches of its length. In the cap at one end of the still a threaded hole was tapped near the edge to receive the exit pipe, which was one-half inch inside diameter. This pipe was slightly bent and about a foot long. It was coupled by a union to a longer pipe of the same diameter which passed through a water jacket to the first receiver. From the receiver an exit tube led through a small Liebig condenser to a second and smaller receiver, intended to catch any overflow and any low boiling bodies which might not condense in the first receiver, from the considerable rise in temperature there. The exit tube from the second receiver passed through three successive bottles.



Set-up of apparatus for normal distillation, showing pyrometer, still, condensers, receivers, wash-bottles, and gas-meter.



Set-up for steam distillation, showing boiler connected at the head of line, and gas-meter removed,

the first of which was empty and reversed so as to act as a safety bulb and prevent the sucking back of the absorbing medium, and the second and third of which were partly filled with a heavy drip oil fraction. From the 1st bottle the exit led to a gas meter reading to .0001 cubic feet. The gas leaving the meter was burned. At the entrance to the second a condenser a valve was inserted to permit of the sampling of the gas during the run. The gas was also sampled after leaving the meter.

At first the temperatures were recorded by a 0°-550°C thermometer, but this was soon replaced by a platinum-platinumrhodium thermocouple in circuit with a Hopkins direct reading voltmeter, reading to tenths of degrees Centigrade.

The still itself was covered by a rectangular galvanized iron cover which was heavily lined with asbestos. This, having no bottom, fitted over the still and minimized radiation losses and equalized the temperature.

In order to make the distillations under reduced pressure the meter was removed from the line



Still, (covered), showing exit pipe.

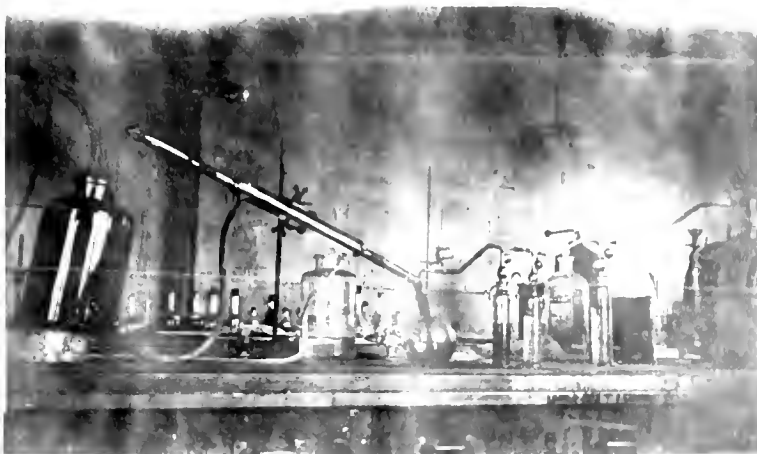


First Condenser.

and the final exit tube was connected to a motor-driven suction pump giving a vacuum of 25" of mercury.

In order to make the runs in atmosphere of steam a 1/2" hole was tapped into the cap on the heretofore closed end of the retort and a small steam boiler of about six gallons capacity was connected to the retort by a three-eighths inch diameter pipe. The boiler was equipped with a pressure gauge reading in "pounds gauge", with an adjustable safety valve, and with two small globe valves, one for regulating the flow of steam into the retort and the other for admitting a supply of fresh water when necessary to replenish the boiler. The boiler was heated by its own burner. The line between the boiler and the still was made as short as possible and was wrapped with asbestos to minimize condensation. Attempts were made to superheat the steam, but this did not prove successful.

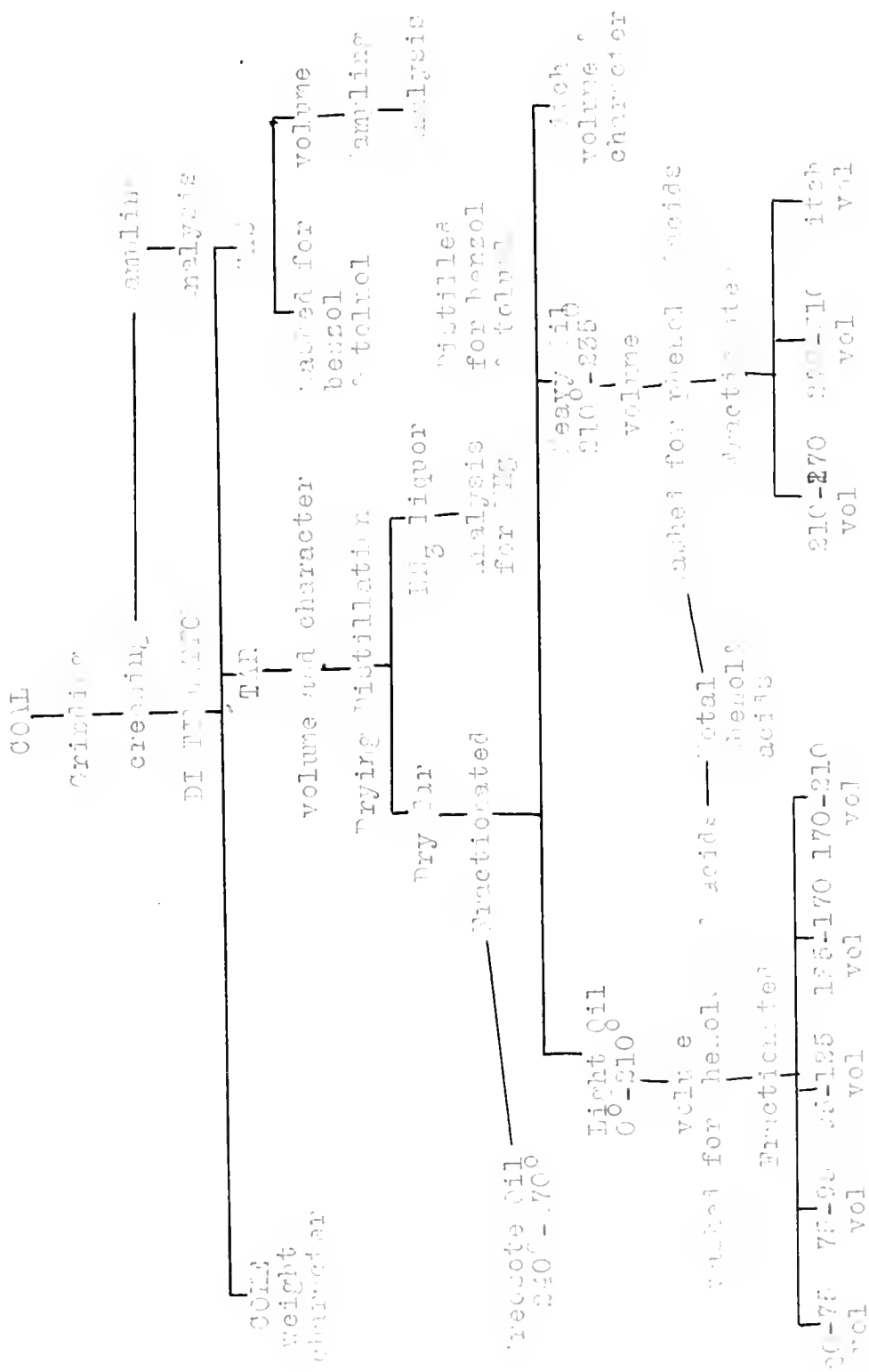
The rest of the apparatus was that necessary for ordinary laboratory analyses, distillations, etc. where necessary, it will be described in its proper place.



Showing tar receiver, second condenser,
overflow receiver, wash-bottles, and
gas-meter.



Showing still, with supporting stand,
and burners.



Material.

Three different samples of coal were used in this investigation, shipped from the Cambria Fuel Company, Cambria, Wyoming. They were labelled "sample 1, average of coal shipped; sample 2, cannel coal; sample 3, high ash splint." Samples 1 and 3 were obviously rather poor coals, especially the first. The second was evidently a good coal. The samples had not been washed, and contained some refuse. Sample three was quite dirty and had a considerable quantity of pyrites and slate mixed with it.

Grinding.

The sample was first crushed in a jaw crusher to pieces about the size of a pea, and was then passed through steel rolls until practically all would pass through a 10-mesh sieve. The sample for analysis was then taken by means of a Jones sampler. This sampler consists of a galvanized iron trough cut into parallel compartments by walls extending across the shorter dimension. The bottoms of the alternate compartments slant to one side and are open so as to divert one-half of the material to that side.

The rest of the compartments act in a similar way diverting the rest of the sample to the other side. There being the same number of compartments operating in each direction the sample is accurately halved. Two troughs catch the two parts. One half is returned to the main sample, and the other is again put through the sampler. The operation is repeated until a sample of suitable size is secured.

The entire product from the rolls was sifted, and only that portion from 10 to 20 mesh was used during the investigation, the rest being rejected. The available portion amounted to about one-half the whole. From observation it seems that a large part of the undesirable waste material, such as pyrites, slate, etc., was thus eliminated.

Distillation.

charges of five pounds of the coal were used. The sample was charged through a two inch hole tapped in the center of the exit end of the retort, and the hole, which was threaded, was closed by a plug screwed into the cap. The coal was spread evenly throughout the retort, which was then placed on the stand and covered. The connections to the line were made, the thermocouple inserted, and the run started. The readings of the gas meter and temperature were taken as well at the time of starting. The heat supplied was so adjusted that it took from three to four hours to reach a temperature of 550°C . It was found necessary to use additional burners to reach this temperature on account of the radiation at the high temperatures, and the result was that the time necessary to reach the maximum temperature sometimes varied considerably. It was decided, however, that the results, especially in a test on such a comparatively small scale, were not appreciably affected by this variation in time. After reaching the maximum temperature the distillation was carried on at that temperature until the distillate ceased to come over.

This point was reached about three and a half hours after the maximum temperature was reached, or about six and a half to seven hours after the run was started. The heat was then turned off and the line opened to prevent any back suction. The tar and drip oil containers were then removed for the fractionation of their contents. The reading of the meter was taken and recorded. After the retort had cooled down it was cleaned out and the coked residue was weighed and its character studied.

During the run samples of the gas were taken between the first container and the second condenser, and also after the meter. These were subsequently analysed. It was decided after the first runs that it was unnecessary to take regular time observations, but rather to keep conditions as near as possible the same during the several runs.

The above is a description of a distillation under normal conditions. As has been stated each coal was distilled under three conditions: Normal, partial vacuum, and steam. When the partial vacuum was used,

the meter had to be removed from the line, since it would not operate correctly under suction. The exit tube was then connected to the suction line, the vacuum in which was induced by a small electrically driven pump. No gauge was used to indicate the degree of vacuum. It was necessary at times to reduce the draw on the line as the flow of gas became too great to insure complete condensation and satisfactory washing of the gas.

For steam distillation the boiler described above was used, steam being supplied at about two pounds gauge. This pressure had to be regulated when the distillation became too rapid for the same reasons as stated under vacuum distillation.

In order to sample the gas during the vacuum runs, it was necessary to shut off the suction, wait until the pressure was slightly more than atmospheric, and then sample by aspiration. No difficulties were experienced in sampling during the steam runs. It was decided however, that the variation in the composition of the gases from the same coal under different conditions was not great enough to warrant the analysis of a complete set of the gases.

Coke.

The coke from the same coal distilled under different conditions varied but slightly in amount. What variation there was, was probably due more to loss in handling and inaccuracy in weighing rather than to conditions of distillation. It would seem at first thought that there should be a greater amount of distillate and less coke or residues under the vacuum and steam distillations, but such did not appear to be the case in the present investigation.

The coke from the different samples varied considerably in amount, the third sample as was deduced from its appearance and analysis, giving the greatest amount of residue. The coke from the second sample, (the cannel coal) was an excellent low temperature coke, while that from the other two samples was poor. The good coke was of firm texture, well bound together, and consequently retentive of its shape under pressure, and yet quite porous and light. No tests were made with it, but it presented the appearance of a good coke fuel. The yield in its case was lower than with either of the other coals.

The poor coke from the other two samples of coal was loose and crumbly, and of little use as a fuel, unless it could be used in briquetting. It was mostly in the form of breeze when taken from the retort, showing that there was little or no binding tendency, and that lumps there were easily crumbled in the fingers.

Beyond weighing the coke and examining it nothing further was done with it,

Gas.

As previously described, the gases evolved during the distillation were sampled at two places and at intervals during the run. The volume of the gas was measured only in those runs under normal conditions, it being advisable to use the meter with the vacuum and steam distillations. The gas after leaving the line was burned. It gave a luminous flame, and the products of combustion had a very offensive odor, as did also the gas itself. Considerable sulphur was present, as was evidenced by this odor. The gas was tested for ammonia at the two sampling points, but practically none was found, indicating that all the ammonia remained in

gallons \pm ton, an error of 50 would not make much difference. In order to secure more accurate results a much larger sample of the original coal, perhaps 100 pounds, should have to be taken.

At first an attempt was made to use oleic acid for the absorption of the benzol and toluol from the gas, but this proved quite unsuccessful. It was found that during the run the oleic acid solidified. On investigation it was decided that the resulting solid was probably isoleic or elaidic acids, these being formed, respectively by the action of sulphuric and nitrous acids on oleic acid. The solidification where oleic acid was used naturally rendered the benzol and toluol determinations useless.

Distillation of Tar. Outline.

I. Properties and Characteristics of Coal Tar.

1. Factors influencing properties and characteristics.
2. Properties and characteristics of specific tars.
3. Reasons for distilling tar.
4. Ratio of tar to water.
5. General methods of distillation.

II. Preliminary Distillation.

1. Drying operation.
 - a) Reasons for drying.
 - b) Practical methods and results.
2. Distillation of dry tar.
 - a) Light oil. ($0-210^{\circ}$)
 - b) Heavy oil. ($210-325^{\circ}$).
 - c) Pitch. (325° and up.)
 - d) Relations of different fractions to the whole.

III. Preparation of Fractions for Further Distillation.

1. Determination of phenols and acids.
2. Washing.

IV. Distillation of Fractions.

1. Light oil.
 - a) Low boiling bodies ($20^{\circ}-75^{\circ}$)
 - b) Crude benzol ($75^{\circ}-95^{\circ}$)
 - c) Crude toluol ($95^{\circ}-125^{\circ}$)
 - d) Crude solvent naphtha ($125^{\circ}-170^{\circ}$)
 - e) Crude heavy naphtha ($170^{\circ}-210^{\circ}$)
 - f) Residue (above 210°)
2. Heavy oil.
 - a) $210^{\circ}-250^{\circ}$
 - b) $250^{\circ}-270^{\circ}$
 - c) $270^{\circ}-310^{\circ}$
 - d) Residue above 210°
3. Pitch.

V. Specific Tars.

Coal tar is a complex mixture of chemical compounds, chiefly of the aromatic series. In addition to the chief constituents there is always a large number of secondary compounds present, and due to the action of heat the specific compounds are often changed, partly into compounds belonging to other series and partly into compounds of the same series. It has been proven that the nature of the raw material, and the temperature of the carbonisation from which the tar results, affect the chemical composition of the tar. Shaly coal and cannel coal give tars containing a quantity of bodies of a paraffinoid nature. Tars from low temperature carbonisation differ decidedly from tars from the same material carbonised at high temperatures. In low temperature tars the amount of free carbon is small, the phenols are of a different series in addition to those of the carbolic series, etc., while on the other hand, tars from high temperature distillation predominate with respect to hydrocarbons of the benzene, naphthalene, and anthracene series. Also the percentage of free carbon is high.

In the work done by the authors, as has been stated, there were three sets of carbonization conditions; air, vacuum, and steam. The tar resulting ranged in appearance from black to a rich brown, with varying thicknesses of layers separating out on standing. The tars, with one exception were lighter than water. This is to be expected with low temperature work. The viscosities of all the tars were low--- a marked difference from high temperature tars. The percentage of water in the tars from air and vacuum distillation ranged between the limits of 53 and 59.7 . It was, of course inadvisable to determine the water driven over in the steam distillation.

Coal tar without distillation is practically without commercial value. The object of distillation therefore, is to develop its usefulness, and necessarily its commercial value. The manufacturers of coal tar products begin by fractional distillation of the tar, and the process is much the same in all plants, except in certain details, such as number of cuts to be made, point at which these cuts are taken off, quality of pitch, etc. The distillation is accomplished in most instances by a naked flame, though sometimes by means of steam.

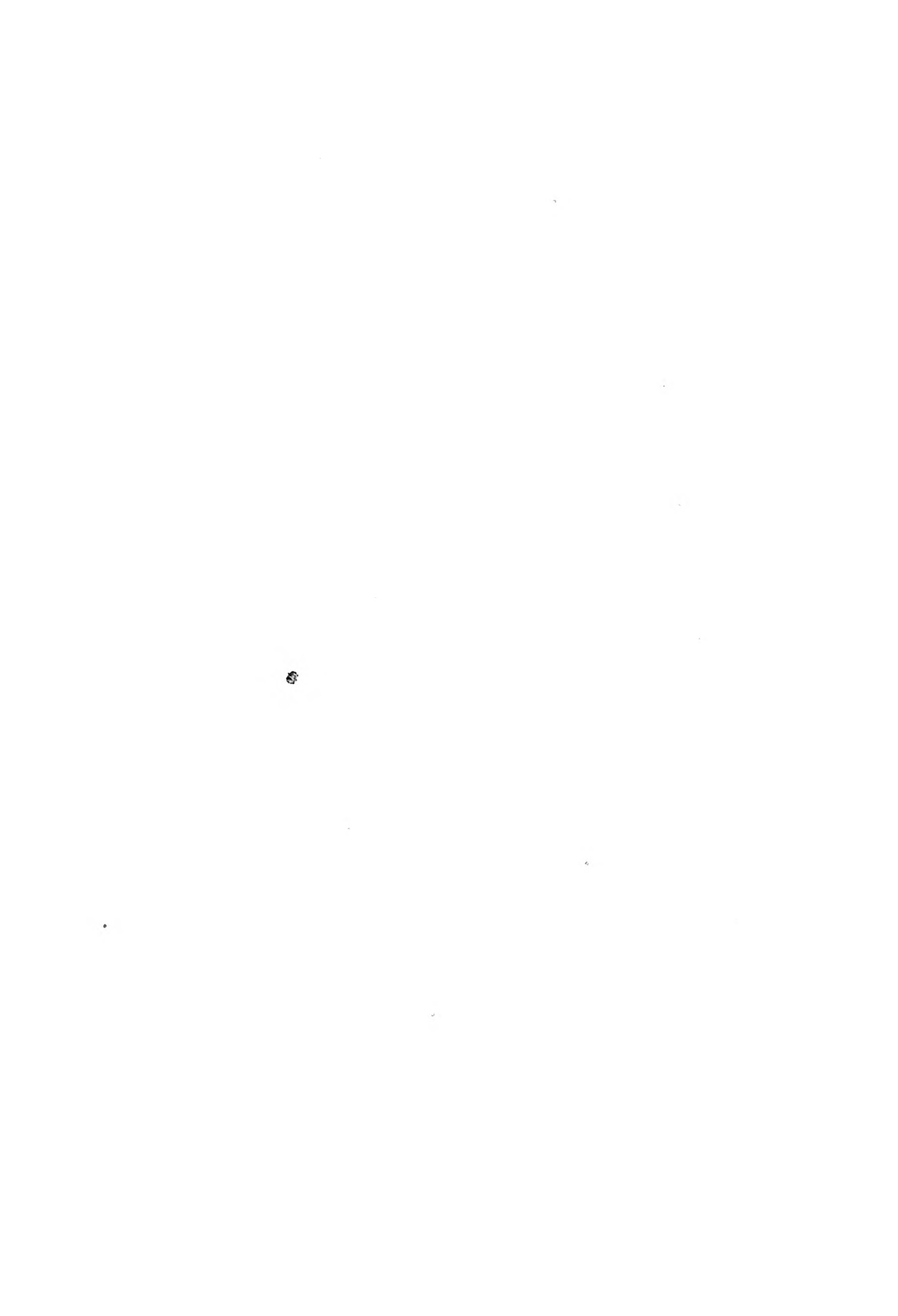
Steam distillation is used where the tar is to be used in the manufacture of roofing felt, impregnation of paving blocks, etc.

Preliminary Distillation.

The apparatus used in the drying and fractionation of the tars consisted of an ordinary round-bottomed side delivery distilling flask of 500cc. capacity, a large Liebig condenser, a receiver, and a thermometer reading to 375°C .

A sample of about 210 cc. was taken from the well-mixed tar and heated up to 125°C to expel as much of the water as possible. This drying operation was necessary with all tars, and in some cases it was found to be quite difficult and tedious due to the lack of special apparatus. Great care had to be taken to prevent the tar from "priming", boiling over, and spoiling the run. It was found that only by heating the tar at the surface could the water be driven off successfully.

Obviously, in carrying the temperature up to 125°C some of the lighter fractions were driven over with the water. The distillate, then, separated into two layers, and after the volume of water had been



recorred, the top layer, consisting of the lighter fractions, was separated from the water and poured back into the dried tar. This operation probably caused a slight loss and the consequent discrepancy in the results as regards the lower boiling fractions. There was still a slight amount of moisture left in the tar, but it was so slight as to cause no trouble, and was subsequently removed in the next fractionation.

The tar was now ready for the primary distillation into the three major fractions: light oil, up to 210° , heavy oil, up to 325° , and pitch, above 325° . This distillation was carried on very slowly in order to get all of the fraction out below the temperature at which the cut was made. It is well-known that a distillation or fractionation may be carried out at a certain temperature, and that on cooling and redistillation of the residue a portion may still be secured below that temperature.

Another sample from the tar was distilled and the fraction between 210° and 270° taken as the "core-oil" fraction. Only the volume of this was recorded. The light oil fraction was between 11° and 14° of the tar; the heavy oil fraction between 14° and 51° ; the pitch between 51° and 100° ; and the core-oil fraction between 61° and 71° .

Before further distillation of the above fraction, the benzole and acids were removed by washing with NaOH in a separating funnel. The layer containing the benzole and acids was then run off and the resin liberated with sulphuric acid. The volume of resin and acid was then run off and recovered. The layer of light or heavy oil, as the fraction happened to be, was washed and the diminished volume ascertained for reference in computing results.

The fractions were then ready for further distillation. Owing to the small volume of the fractions it was necessary to use a small distilling flask, holding about 50 cc, and a short straight condenser for this work. The light oil fraction was cut as follows:

Low boiling bodies	20° to 75° Cent.
Crude Benzol	75° to 85°
Crude Toluol	85° to 125°
Crude Solvent Naphtha	125° to 170°
Crude heavy Naphtha	170° to 210°
Residue	210° up

The residue from the fractionation of the light oil was added to the heavy oil fraction, which was then distilled as cut as follows:

First	210° to 270°
Second	270° to 290°
Third	290° to 310°
Pitch	310° up

It will be noticed that the higher boiling fractions are not named. In attention is made to them, but according to Lewis¹ they are probably low-boiling polyhydric phenols.

In practice there are a number of methods of dehydrating the tar. When large quantities of tar are used a separation of the immiscible liquor and the tar is accomplished merely by settling the tar in a large cistern. In Germany an efficient method is in use in which the tar is spread in thin layers on broad overflow spouts. The tar, slightly heated in running over the spouts, separates from the water. There are many other methods, all accomplishing the same result with more or less efficiency.

1. Lewis: Carb. nitration of coal.

specific Tar.

For 1. Coal 1. Thermal distillation.

This tar had a total volume of 150 cc., of which 175 cc. was ammoniacal liquor. A sample of 100 cc. of the crude tar yielded the following preliminary distillation:

	Vol.	Per cent.
Water	37cc.	24.60
Light Oil	15 cc.	10.00
Heavy Oil	47.cc.	31.30
Pitch	51 cc.	33.60
	<hr/>	<hr/>
	150 cc.	100.00

A sample of 100 cc. when distilled for the cresote fraction, between 340° and 370° , gave 7 cc., or 7% of the tar.

A 20 cc. sample of the light oil from this tar, gave on fractionation, the following results:

Fraction	volume	light oil	cresote tar
$20^{\circ} - 35^{\circ}$	1.1 cc.	5.5	0.55
$35^{\circ} - 125^{\circ}$	2.2 cc.	11.0	1.10
$125^{\circ} - 170^{\circ}$	2.8 cc.	14.0	1.40
$170^{\circ} - 210^{\circ}$	4.0 cc.	20.0	2.00
210° -----	6.9 cc.	34.5	3.45
	<hr/>	<hr/>	<hr/>
	20.0 cc.	100.0	10.00

47 cc. sample of the heavy oil fraction gave the following fractions on distillation:

Fraction	volume	heavy oil	crude tar
-- 210°	4.0 cc.	3.3	2.1
210° - 250°	6.0 cc.	12.75	4.00
250° - 270°	8.0 cc.	17.60	5.33
270° - 310°	4.5 cc.	9.37	3.00
310° ----	24.5 cc.	52.19	16.32

The determination of phenols and acids in this tar was made volumetrically, and subsequently this method was abandoned for the liberation method. The results obtained with this tar were as follows:

Light oil 20 cc. gave 0.2 cc. phenol = 1.0 1.0. = 0.1 tar.
Heavy oil 47 cc. " 0.17 cc. " = 0.4 1.0. = 0.12 "

Tar # 4.* Coal #1. Vacuum Distillation *

Total volume of tar, 480 cc; of this 1.9 cc. was ammoniacal liquor. A 200 cc. sample yielded on distillation the following fractions:

over	1.83 cc.	41.3,
Light oil	23 cc.	11.0
Heavy oil	61 cc.	30.5
pitch	<u>34 cc.</u>	<u>17.0</u>
	200 cc.	100.0

* Three tars from each coal were taken for phen.

The creosote fractions were treated on the vacuum or steam distillations, since it was assumed that the variation would not be considerable.

The phenols and acids were not removed from the fractions by shaking them in separatory funnels with concentrated NaOH solution, separation, and then washing the residual tar. The sodium phenolate solution, together with the washings, is placed in a graduate and acidified with sulphuric acid in order to liberate the phenol, which then rises to the top of the mixture. In case the separation was not rapid enough, salt was added to the mixture, in order to increase the specific gravity of the solution and thus hasten the flotation of the phenol. The volume of phenol and acid was then read directly. The reduction in volume of the original fraction, due to the absorption by the NaOH, was noted and the percentage of phenol and acids estimated for further check. The treated fractions were not ready for further fractionation.

Light oil, Tar #4. Volume 22 cc.

Fraction	Volume	light oil	crude tar
20° - 75°	1.2 cc.	5.5	0.60
75° - 125°	2.6 cc.	11.8	1.50
125° - 170°	7.2 cc.	32.7	3.60
170° - 210°	3.2 cc.	14.5	1.60
210° ----	2.8 cc.	12.7	1.40
Phenols	5.0 cc.	22.7	2.50
	<u>22.0 cc.</u>	<u>100.0</u>	<u>11.00</u>

Heavy oil, Tar #4. Volume 65.8 cc. (Residue from light oil fractionation, 2.3 cc., was added.)

Fraction	Volume	heavy oil	crude tar
--- 210°	4.25 cc.	6.67	2.12
210° - 250°	11.00 cc.	17.21	5.50
250° - 270°	4.20 cc.	6.67	2.10
270° - 310°	10.50 cc.	16.45	5.25
310° ----	21.85 cc.	34.20	10.32
Phenols	<u>12.00 cc.</u>	<u>18.80</u>	<u>6.00</u>
	65.80 cc.	100.00	31.92

Tar #7, Coal #1. Steam Distillation.

Total volume of tar: 525 cc. No further data was secured from this tar, due to loss before distillation was accomplished.

Tar #2. Coal #2. Distilled in air.

Total volume: 467 cc. This tar on standing separated into two layers, water on top and tar underneath. The volume of the top layer was 300 cc; that of the bottom layer was 167 cc.

The top layer was distilled in the usual manner, and yielded the following results:

up to 125°	175 cc. water
80°- 210°	7.5 cc. light oil

The light oil was added to a 150 cc. sample from the bottom layer, and the mixture was fractionated.

Fraction	Volume
Water - 125°	16 cc.
Light oil - 210°	28 cc.
Heavy oil 210°- 315°	48 cc.
Residue 315°-----	19 cc.

These results could not be figured to percentages on account of the non-homogeneity of the sample. It was necessary, therefore, to calculate the fractions on the basis of the total tar, and from these results calculate the fraction percentages.

Fraction	Volume	% crude tar
Water - 125°	202.4 cc.	43.2%
Light oil	42.6 cc.	9.1
Heavy oil	10.21 cc.	10.2
Residue	<u>149.00 cc.</u>	<u>29.5</u>
	467.2 cc.	100%

A 107 cc. sample was fractionated for creosote oil and gave the following results:

Water - 125° 11.4 cc.
 Creosote oil 240°- 270° 12.0 cc. 6.15 (crude tar)

Light oil fraction. Volume: 42.6 cc.

Fraction	Volume	Light oil	Crude tar
70° - 85°	3.4 cc.	7.9	.727
95° - 125°	5.5 cc.	15.2	1.590
125° - 170°	11.5 cc.	26.9	2.180
170° - 210°	6.6 cc.	15.3	1.410
210° ----	4.2 cc.	9.86	1.368
Phenols and acids	<u>10.4 cc.</u>	<u>24.40</u>	<u>2.520</u>
	42.6 cc.	49.60	9.100

Heavy oil fraction. Volume 33.2 cc.

Fraction	Volume	Heavy oil	Crude tar
----210°	9.0 cc.	16.9	3.31
210° - 250°	11.4 cc.	21.4	4.18
250° - 270°	5.0 cc.	9.4	1.64
270° - 310°	9.55 cc.	17.3	3.54
310° ----	6.7 cc.	12.5	2.40
Phenols and acids	<u>10.5 cc.</u>	<u>19.7</u>	<u>5.6</u>
	33.2 cc.	76.0	19.10

Tar No. 3-1-2. Distilled in Vacuum.

10.1 volume 57 cc. - 250 cc. sample of fractionation yielded the following:

Fraction	Volume	crude tar
Up to 125°	65. cc.	2.5
Light oil	27.0 cc.	13.5
Heavy oil	57.0 cc.	23.6
Titch	50.0 cc.	15.0

Light oil fraction.

Volume: 27 cc.

On extraction with NaOH a reduction of 5.25 cc. was noted. In liberation of the phenolic solution only 5.10 cc. of phenols and acids was secured. The difference is probably due to the presence of some tar, and to loss in handling. Fractionation gave:

Fraction	Volume	light oil	crude tar
20° - 25°	1.6 cc.	5.11	.80
25° - 125°	1.6 cc.	5.91	.80
125° - 170°	6.0 cc.	23.2	3.00
170° - 210°	6.0 cc.	23.2	7.40
210° -----	6.5 cc.	24.0	3.25
Phenols and acids	<u>5.25 cc.</u>	<u>11.1</u>	<u>2.12</u>
	27.00 cc.	99.52	15.47

Heavy oil fraction. Volume: cc.

Fraction	Volume	heavy oil	crude tar
---210°	5.2 cc.	8.5 %	1.6
210° - 250°	4.4 cc.	7.6	2.2
250 - 270°	5.4 cc.	9.2	2.7
270° - 310°	10.6 cc.	12.3	5.5
310° ---	19.4 cc.	31.5	9.7
Phenols & acids	<u>15.0</u> cc.	<u>25.8</u>	<u>7.5</u>
	58.0 cc.	99.35	29.0

Tar #8. Coal #2. Distilled in steam.

All tars from steam distillation were filtered.

Volume of this tar after filtration: 523 cc.

A 300 cc. sample gave the following results:

Fraction	Volume	crude tar
Water --- 125°	64.0 cc.	21.5 %
Light oil	36.5 cc.	12.0
Heavy oil	99.5 cc.	33.15
Pitch	<u>100.0</u> cc.	<u>33.3</u>
	300.0 cc.	99.7 %

Light oil fraction. Volume 56.5 cc.

Fraction	Volume	light oil	crude tar
20° - 35°	1.5 cc.	4.1	.496
35° - 125°	2.5 cc.	6.35	.855
125° - 170°	7.5 cc.	21.6	2.5
170° - 210°	16.5 cc.	47.2	.3
210°----	6.7 cc.	16.5	2.7
Phenols & acids	<u>1.8 cc.</u>	<u>4.92</u>	<u>.356</u>
	56.5 cc.	99.97	11.956

Heavy oil fraction. Volume: 99.0 cc.

Fraction	Volume	heavy oil	crude tar.
----210°	--	--	--
210° - 250°	16.0 cc.	15.2	6.0
250° - 270°	14.0 cc.	14.1	4.66
270° - 310°	27.0 cc.	27.3	9.00
310°-----	32.2 cc.	35.5	11.75
Phenols & acids	<u>4.8 cc.</u>	<u>4.35</u>	<u>1.6</u>
	99.0 cc.	99.5	32.39

Tar #3. Coal #3 Distilled in air.

Total volume: 434 cc. + 270 cc. sample = 704 cc.

Fraction	Volume	crude tar
Water -----125°	92.0 cc.	45.6
Light oil	24.0 cc.	12.0
Heavy oil	57.0 cc.	30.5
Litch	<u>57.2 cc.</u>	<u>9.5</u>
	200.0 cc.	97.6

A sample of 200 cc. was fractionated for the creosote fraction the following:

Creosote oil 210° - 270° 15.7 cc. 0.27

Light oil fraction. Volume 40.0 cc.

Fraction	Volume	Light oil	Creosote
20° - 95°	1.2 cc.	15.0	1.50
95° - 125°	1.2 cc.	20.5	2.46
125° - 170°	11.5 cc.	2.7	3.45
170° - 210°	4.5 cc.	11.0	1.35
210° ---	2.5 cc.	6.25	.75
Phenols and Acid.	<u>1.0 cc.</u>	<u>20.0</u>	<u>2.4</u>
	39.9 cc.	99.45	11.97

Heavy oil fraction. Volume: 51.0 cc.

Fraction	Volume	Heavy oil	Creosote
--- 210°	6.0 cc.	11.7	2.18
210° - 250°	6.7 cc.	10.1 %	2.44
250° - 270°	4.4 cc.	8.62	1.6
270° - 310°	6.2 cc.	12.15	2.87
310° -----	16.2 cc.	51.8	5.89
Phenols & Acid.	<u>11.2 cc.</u>	<u>21.9</u>	<u>4.0</u>
	50.7 cc.	99.27	18.45

Tar 6. Coal 5. Distilled in Vacuum.

Total volume of tar: 317 cc. + 300 cc. sample
gave on fractionation:

Fraction	Volume	crude tar
Water - 125°	175.0 cc.	17.60
Light oil	27.0 cc.	9.00
Heavy oil	58.0 cc.	19.50
Slitch	<u>42.0 cc.</u>	<u>14.00</u>
	300.0 cc.	99.90

Light oil fraction. Volume: 27 cc.

Fraction	Volume	light oil	crude tar
20° - 95°	2.4 cc.	8.2	.80
95° - 125°	1.0 cc.	3.71	.556
125° - 170°	8.0 cc.	29.6	2.88
170° - 210°	9.0 cc.	52.4	3.01
210° ---	4.6 cc.	17.05	1.12
Phenols & Acids	<u>2.5 cc.</u>	<u>8.26</u>	<u>.835</u>
	27.5 cc.	100.0	8.77

Heavy oil fraction. Volume 58.0 cc.

Fraction.	Volume	heavy oil	crude tar
---210°	2.0 cc.	6.25	1.2
210° - 250°	9.0 cc.	28.2	3.44
250° - 270°	6.0 cc.	18.71	3.32
270° - 310°	7.0 cc.	21.81	4.25
310° ----	10.0 cc.	3.13	.60
Phenols & acids	<u>7.0 cc.</u>	<u>21.81</u>	<u>4.15</u>
	52.0 cc.	99.885	19.52

Tar 9. Coal 5. Distilled in team.

Total volume of tar: 267 cc. 267 cc. sample
gave on distillation:

Fraction	Volume	crude tar
Water---- 125°	71.8 cc.	25.9
Light oil	25.5 cc.	8.7
Heavy oil	68.0 cc.	21.8
Pitch	<u>102.7 cc.</u>	<u>3.4</u>
	267.0 cc.	31.8

Light oil fraction.

Volume 25.5 cc.

Fraction	Volume	light oil	crude tar
20°- 95°	2.0 cc.	0.5	.754
95°- 125°	2.5 cc.	9.77%	.860
125°- 170°	6.4 cc.	27.2	2.4
170°- 210°	7.0 cc.	22.8	2.62
210°---	3.5 cc.	14.01	1.25
Phenols & acids	<u>2.5 cc.</u>	<u>10.6</u>	<u>.975</u>
	25.5 cc.	99.81	8.79

Heavy oil fraction. Volume: 69.0 cc.

Fraction	Volume	heavy oil	crude oil
---- 210 ⁰	3.2 cc.	4.54	1.19
210 ⁰ - 250 ⁰	12.5 cc.	18.1	4.7
250 ⁰ - 270 ⁰	9.9 cc.	15.05	3.54
270 ⁰ - 310 ⁰	18.5 cc.	20.8	6.92
310 ⁰ ---	11.8 cc.	17.8	3.74
Phenols & acids	<u>14.0 cc.</u>	<u>20.5</u>	<u>5.24</u>
	69.0 cc.	69.35	25.1

CHEMICAL ANALYSES

Average Gas Analyses.

<u>Components.</u>	<u>Coal #1.</u>	<u>Coal #2.</u>	<u>Coal #3.</u>
CO ₂	4.4	6.55	11.1
Illuminants	0.0	2.6	4.05
O ₂	2.5	0.72	10.5
CO	6.5	7.95	2.92
CH ₄	25.9	25.65	15.97
H ₂	51.6	21.6	41.00
N ₂ (by diff.)	<u>29.10</u>	<u>57.15</u>	<u>14.46</u>
	100.00	100.00	100.00

Average Coal Analyses.

<u>Component</u>	<u>Coal #1.</u>	<u>Coal #2</u>	<u>Coal #3.</u>
V. C.M.	42.68	49.95	56.07
Moisture	2.22	4.54	2.4
Ash	26.35	11.06	40.31
Nitrogen	1.03	1.67	1.50
Sulphur	3.24	1.72	4.10
Fixed Carbon	28.75	54.47	21.22

TABULATED DATA.

The column headed " Actual ", on each page, refers to the data actually secured from the sample treated.

The column headed " Total " refers to the results that would have been obtained, had the entire sample been used in securing the particular value in question.

The column headed " Per Ton of Coal" contains the values calculated on the basis of an initial sample of 2000 pounds of coal.

The first column is experimental, and the second and third are calculated.

Whenever a fraction is used in the " Actual " column, such as $45/200$, the indication is that the numerator represents the amount secured from the denominator. In this case a 200 cc. sample gave 45 cc. of the fraction sought for.

COAL # 1, DISTILLED IN AIR

<u>Item.</u>	<u>Actual</u>	<u>Total</u>	<u>Per ton of Coal</u>
Coal used	5 lbs	5 lbs	2000 lbs
Joke formed	3.25 lbs	3.25 lbs	1300 lbs
Volume of gas	6.818 cu.ft.	6.818 cu.ft.	2725 cu.ft.
Benzol & Toluol	1.9 cc.	1.9 cc.	0.201 gal
Total Lar	460 cc.	460 cc.	48.6 cc
Ammonia liquor	57/150 cc.	175 cc.	18.5 gal
Light oil	15/150 cc.	46 cc.	4.86 gal
Heavy oil	47/150 cc.	144 cc.	15.3 gal
Creosote oil	7/150 cc.	32.1 cc.	3.4 gal
Pitch	20.7/150 cc.	95 cc.	10.1 gal
20° - 75°	0	0	0
75° - 95°	1.1/2	2.55 cc.	.268 gal
95° - 125°	2.2/20	5.06 cc.	.535 gal
125° - 170°	5.8/20	10.35 cc.	1.01 gal
170° - 210°	4.0/20	9.2 cc.	.975 gal
210°-----	5.9/20	13.35 cc.	1.02 gal
Phenols & acids from light oil	----	-----	.20 lbs
---210°	4.0/47	12.25 cc.	1.3 gal
210° - 250°	6.0/47	18.4 cc.	1.95 gal
250° - 270°	8.0/47	24.5 cc.	2.6 gal
270° - 310°	4.5/47	13.8 cc.	1.46 gal
310°---	24.5/47	75.0 cc.	7.95 gal
Phenols & acids from heavy oil	----	-----	.19 lbs
(NH ₄) ₂ SO ₄	-----	-----	3.59 lbs

Coal - 1. DISTILLED IN VACUUM.

<u>Item.</u>	<u>Actual</u>	<u>Total</u>	<u>per ton of Coal</u>
Coal used	5 lbs	5 lbs	2000 lbs
Coke formed	3.25 lbs	3.25 lbs	1300 lbs
Volume of gas	-----	-----	-----
Benzol & Toluol	-----	-----	-----
Total tar	480 cc.	480 cc.	10.7 gal
Ammonia liquor	85/200	199 cc.	21.0 gal
Light oil	22/200	52.8 cc.	5.58 gal
Heavy oil	61/200	140.4 cc.	15.45 gal
Creosote oil	-----	-----	-----
Pitch	54/200	81.5 cc.	8.6 gal
20°- 75°	0	0	0
75°- 95°	1.2/22	2.88 cc.	.305 gal
95°- 125°	2.6/22	6.25 cc.	.61 gal
125°- 170°	7.2/22	17.3 cc.	1.83 gal
170°- 210°	3.2/22	7.2 cc.	.814 gal
210°----	2.8/22	6.75 cc.	.74 gal
Phenols & acids from light oil	5/22	1.2 cc.	.95 lbs
----210°	4.25/23.8	1.02 cc.	1.18 gal
210°- 250°	11/23.8	2.64 cc.	2.8 gal
250°-270°	4.2/23.8	1.01 cc.	1.7 gal
270°- 310°	10.5/23.8	2.52 cc.	2.68 gal
310°-----	8.25/23.8	2.1 cc.	2.25 gal
Phenol & acids from heavy oil	-----	-----	-----
(NH ₄) ₂ SO ₄	-----	-----	-----

Coal # 3. REFINED IN AIR.

<u>Item.</u>	<u>Actual</u>	<u>Total</u>	<u>Heat in Coal</u>
Weight Coal	5 lbs	5 lbs	2000 lb
Coke formed	2.75 lbs	2.75 lbs	1100 lb
Volume of gas	10.4 cu.ft.	10.4 cu.ft.	4160 cu.ft.
Benzol & Toluol	5.5 cc.	5.5 cc.	.57 gal
Total tar	467 cc.	467 cc.	49.3 gal
Ammonia liquor	262.4 cc.	262.4 cc.	21.4 gal
Light oil	42.6 cc.	42.6 cc.	4.5 gal
Heavy oil	82.25 cc.	82.25 cc.	.7 gal
Creosote oil	28.8 cc.	28.8 cc.	3.04 gal
Pitch	140 cc.	140 cc.	14.75 gal
20°- 75°	1.5 cc.	1.5 cc.	.16 gal
75°- 95°	1.9 cc.	1.9 cc.	.20 gal
95°- 125°	6.5 cc.	6.5 cc.	.68 gal
125°- 170°	11.5 cc.	11.5 cc.	1.22 gal
170°- 210°	6.6 cc.	6.6 cc.	.70 gal
210°----	4.2 cc.	4.2 cc.	.44 gal
Phenols & acids from light oil	-----	-----	.41 gal
----210°	9.0 cc.	9.0 cc.	1.57 gal
210°- 250°	11.4 cc.	11.4 cc.	2.00 gal
250°- 270°	5.0 cc.	5.0 cc.	.88 gal
270°- 310°	9.65 cc.	9.65 cc.	1.70 gal
310°---	6.7 cc.	6.7 cc.	1.17 gal
Phenols & acids from heavy oil	-----	-----	1.64 gal
(NH ₄) ₂ SO ₄	-----	-----	3.19 gal

Coal # 2. DISTILLED IN VACUUM.

<u>Item.</u>	<u>Actual</u>	<u>Total</u>	<u>Per Ton</u>
Coal used	5 lbs	5 lbs	2000 lbs
Coke formed	3.125 lbs	3.125 lbs	1250 lbs
Gas formed	-----	-----	-----
Benzol & Toluol	-----	-----	-----
Total tar	578.0 cc.	578.0 cc.	61.1 gal
Ammonia liquor	246 cc.	246 cc.	26. gal
Light oil	78 cc.	78 cc.	8.25 gal
Heavy oil	167.0 cc.	167.0 cc.	17.75 gal
Creosote oil	---	---	---
Pitch	86.7 cc.	86.7 cc.	9.16 gal
20°- 75°	1.00 cc.	2.89 cc.	.305 gal
75°- 95°	0.6 cc.	1.75 cc.	.183 gal
95- 125°	1.6 cc.	4.62 cc.	.488 gal
125°- 170°	6.0 cc.	17.3 cc.	1.83 gal
170°- 210°	6.0 cc.	17.3 cc.	1.83 gal
210°----	6.5 cc.	18.8 cc.	1.99 gal
Phenols & acids from light oil	5.1 cc.	8.95 cc.	.945 gal
---210°	3.2 cc.	9.25 cc.	.970 gal
210°- 250°	4.4 cc.	12.7 cc.	1.34 gal
250°- 270°	5.4 cc.	15.6 cc.	1.65 gal
270°- 310°	10.6 c .	31.7 cc.	3.33 gal
310°- -	19.4 cc.	56.2 cc.	5.95 gal
Phenols & acids from heavy oil	----	---	-- 1.59 gal
(NH ₄) ₂ SO ₄	----	----	----

Coal " 3. FILTERED IN AIR.

<u>Item.</u>	<u>Actual</u>	<u>Total</u>	<u>Per Ton</u>
Coal used	5 lbs	51b	2000 lbs
Coke formed	5.75 lbs	5.75 lbs	1500 lbs
Gas formed	7.171 cu. ft.	7.171 cu.ft.	2965 cu.ft.
Benzol & Toluol	2.0 cc.	2.0 cc.	.21 gal
Total tar	454.0 cc.	454.0 cc.	46.5 gal
Ammonia liquor	92/200	109.5 cc.	21.05 gal
Light oil	24/200	52.0 cc.	5.3 gal
Heavy oil	37/200	81.3 cc.	8.3 gal
Cresote oil	15.75/200	21.3 cc.	5.15 gal
Pitch	47/200	122.0 cc.	12.8 gal
200-75°	0	0	0
75° - 95°	5.2/40	6.2 cc.	.675 gal
95° - 125°	.2/40	8.95 cc.	.945 gal
125° - 170°	11.5/40	17.7 cc.	1.44 gal
170° - 210°	4.5/40	5.55 cc.	.585 gal
210°----	2.5/40	2.5 cc.	.262 gal
Phenol & acids from light oil	8.0/40	8.3 cc.	1.005 gal
--- 210°	6.0/39.5	17.0 cc.	1.37 gal
210° - 250°	6.7/39.5	14.55 cc.	1.54 gal
250° - 270°	4.4/39.5	9.55 cc.	1.01 gal
270° - 310°	8.2/39.5	13.45 cc.	1.4 gal
310°----	2.45/39.5	5.72 cc.	.593 gal
Phenol & acids from heavy oil	11.25/31.5	21.1 cc.	2.36 gal
(NH ₄) ₂ SO ₄	---	---	---

Coal # 5. ANALYSED IN VACUUM.

7-15-39

<u>Item</u>	<u>Actual</u>	<u>Net 1</u>	<u>Net 2</u>
Coal used	5 lbs	5 lbs	2000 lb.
Coke formed	5.425 lbs	5.425 lbs	1450 lb.
Gas formed	---	---	---
Benzol & Toluol	4.25 cc.	4.25 cc.	.445 gal
Tot 1 tar	387 cc.	387 cc.	4.9 gal
Ammonia liquor	173/300	225 cc.	2.9 gal
Light oil	27/300	54.0 cc.	7.56 gal
Heavy oil	58/300	70.0 cc.	7.4 gal
Creosote oil	---	---	---
Pitch	42/300	44.1 cc.	5.72 gal
200- 75°)		
75°- 95°			
95°- 125°	1.0/300	1.00 cc.	.137 gal
125°- 170°	3.0/300	10.3 cc.	1.3 gal
170°- 210°	9.0/300	11.6 cc.	1.35 gal
210°---	7.0/300	5.44 cc.	.721 gal
Phenol & acids from light oil	2.7/500	5.21 cc.	.54 gal
---210°	2.0/500	5.23 cc.	.545 gal
210°- 250°	1.0/300	14.1 cc.	2.55 gal
250°- 270°	6.0/300	16.01 cc.	1.7 gal
270°- 310°	7.0/300	12.7 cc.	1.36 gal
310°---	1.7/300	2.75 cc.	.3 gal
Phenol & acids from heavy oil	7.0/310	9.4 cc.	1.15 gal
(NH ₄) ₂ SO ₄	---	---	4.59 lbs.

Co 1 8.

DISTILLATE

Item	Actual	Found	per cent
Coal used	5 lbs	5 lbs	20.0 %
Coke formed	1.75 lbs	5.15 lbs	11.2 %
Gas formed	---	---	---
Benzol & Toluol	12.5 cc.	2.5 cc.	1.51 gal
Total tar	247 cc.	7 cc.	28.7 gal
Ammonia liquor	71.3 cc.	71.3 cc.	7.50 gal
Light oil	23.5 cc.	23.5 cc.	2.41 gal
Heavy oil	39.0 cc.	39.0 cc.	7.50 gal
Grease oil	---	---	---
Pitch	112.7 cc.	112.7 cc.	1.85 gal
20°- 75°) 2. cc.	2. cc.	.211 gal
75°- 95°			
95°- 125°	2.5 cc.	2.5 cc.	.212 gal
125°- 170°	6.4 cc.	.4 cc.	.1 gal
170°- 210°	7.0 cc.	7.0 cc.	.74 gal
210°---	2.5 cc.	2.5 cc.	.207 gal
Phenol & acids from light oil	2.5 cc.	2.5 cc.	.212 gal
--- 210°	5.2 cc.	1.2 cc.	.558 gal
210°- 270°	12.5 cc.	12.5 cc.	1.72 gal
250°- 270°	6.0 cc.	1.0 cc.	.15 gal
270°- 310°	16.5 cc.	1.5 cc.	1.95 gal
310°-	10.1 cc.	2.0 cc.	1.07 gal
Phenol & acids from heavy oil	14.0 cc.	14.0 cc.	1.43 gal
(NH ₄) ₂ SO ₄	---	---	---

COMPARISON OF ANALYSES OF COAL TARS

Item	Coal 1.	Coal 2.	Coal 3.
Coal used	20.0 lbs	20.0 lbs	20.0 lbs
Soot formed	1330 lbs	1335 lbs	1425 lbs
Gas formed	1757 cu.ft.	4153 cu.ft.	455 cu.ft.
Benzol & Methylol	.201 gal	.61 gal	.658 gal
Tot l tar	4.6 gal	2.3 gal	.6 gal
Ammonia liquor	19.75 gal	22.1 gal	17.11 gal
Light oil	5.22 gal	5.63 gal	7.71 gal
Heavy oil	17.58 gal	12.53 gal	7.75 gal
Creosote oil	5.4 gal	5.24 gal	5.15 gal
Pitch	9.55 gal	11.77 gal	9.14 gal
20°- 75°	0	.174 gal	3.85 gal
75°- 95°	.287 gal	.166 gal	4.53 gal
95°- 125°	.577 gal	.467 gal	1.77 gal
125°- 170°	1.43 gal	1.5 gal	.35 gal
170°- 210°	.95 gal	1.37 gal	.113 gal
210°---	.88 gal	.65 gal	.14 gal
Methylol & acids from light oil	.44 gal	.54 gal	.356 gal
---210°	1.19 gal	1.018 gal	.75 gal
210°- 250°	2.38 gal	1.79 gal	1.3 gal
250°- 270°	1.64 gal	1.77 gal	1.22 gal
270°- 310°	2.7 gal	1.67 gal	1.73 gal
310---	3.1 gal	1.7 gal	.57 gal
Methylol & acids from heavy oil	---	1.383 gal	1.72 gal
(NH ₄) ₂ SO ₄	3.35 lbs	3.1 lbs	.39 lbs





